CEMETERIES AND GROUNDWATER: AN EXAMINATION OF THE POTENTIAL CONTAMINATION OF GROUNDWATER BY PRESERVATIVES CONTAINING FORMALDEHYDE

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INTRODUCTION

A study on the effect of burial preservatives on groundwater quality was initiated in the summer of 1990, by the Drinking Water Section of the Water Resources Branch, as a result of public concern that this may be a significant source of groundwater contamination.

The Water Resources Branch conducted a groundwater reconnaissance sampling survey using existing wells at six sites. Analyses were conducted for formaldehyde, nitrates and phosphates. Bacteriological analyses were also done. The sites were predominately in shallow sandy aquifers down gradient of cemeteries.

LITERATURE SURVEY

Two extensive literature surveys were carried out for this project. National and public libraries, both here and in the United States of America were approached for information. Academia and regulatory bodies were also contacted for information. No literature on this subject could be obtained. It may be noted that this investigation is the first of its kind in North America. This initiative may serve as background material to others who may be interested in this subject for further study.

The Ministry, following a lead, extended its survey to Holland, and one publication entitled "Cemeteries as Sources of Contamination" by Dr. F.W.J. Van Haaren was found. The findings of this document have been incorporated into this report.

BURIAL PRACTICES SURVEY

A survey of standard burial practices indicated that in populated areas in Ontario, the majority of bodies (90%) are embalmed and then placed into a casket. Caskets range from soft to hard woods to steel. Steel caskets are hermetically sealed. The casket may be placed into a concrete vault and sealed with impermeable caulking. According to MOE guidelines, the concrete vault is placed into the ground at a minimum depth of 0.5 metres above the highest water table. MOE guidelines also recommend that graves be a minimum of 30 metres from a well or surface water source being used for drinking purposes.

Embalming is the process of sanitizing and preserving human remains to render them safe for handling while retaining the natural appearance of the tissue for funeral viewing purposes. The

process retards putrefaction and lignification by "fixing" the skin and underlying tissues.

The preservative (a formaldehyde solution), is injected at several sites on the body. Two formulae of different concentrations are commonly used. One is used for the circulatory system while the other is injected into the organs located within the thoracic and abdominal cavities displacing the natural body fluids.

DRINKING WATER STANDARDS FOR FORMALDEHYDE

Currently there is no drinking water standard for formaldehyde in Canada. From work done in the U.S, the Emergency Response Group Committee on Toxicology, National Academy of Sciences, has recommended that EPA establish a drinking water standard of 110 micrograms/L (ppb), (Tomkins et al.).

FORMALDEHYDE

Formaldehyde, an animal carcinogen, causes squamous cell carcinomas in nasal cavities of laboratory rats and male mice. Formaldehyde can exert its mutagenic and carcinogenic effects by both damaging DNA and inhibiting its repair (Graftstrom et al.). Neither the U.S nor Canada have established a regulatory standard for formaldehyde in drinking water.

Formaldehyde is produced and sold as water solutions containing variable amounts of methanol. These solutions are complex equilibrium mixtures of methylene glycol, poly (oxymethylene glycols) and hemiformals of these glycols. Formaldehyde is noted for its reactivity and versatility as an intermediate chemical. It is also an active reducing agent. In the presence of an alkali, hydrogen peroxide oxidizes formaldehyde to formic acid. When reacting with metal oxide catalysts, it reduces very easily to methanol. The chemical is oxidized to formic acid and or carbon dioxide and water. It may be noted that analyses involving the addition of chlorine in the processing of samples will result in the reduction of formaldehyde to form carbon dioxide and water. Water wells are commonly disinfected by the addition of chlorine based chemicals.

FORMALDEHYDE AS A PRESERVATIVE

Three different indices of formaldehyde preservative exist:

Low	< 20%
Medium	20-29%
High	>30%

One litre of a formaldehyde based preservative per 5.0 kilograms of body weight is normally used in the embalming process. An additive of 0.18 litres of 32 index in 9 litres of water gives a

solution of 2% formaldehyde, which is a standard concentration used in embalming.

Formaldehyde is used in a number of other practices. It may be interesting to note that formaldehyde is used also in agricultural practises to destroy some fungi, in tanning practices, in the manufacture of plastics and sometimes as a substitute process chemical in the manufacture of combs and buttons (H. C Muldoon & M. Blake, Systematic Organic Chemistry 1957, p.220).

LABORATORY ANALYSIS TECHNIQUE

Formaldehyde is readily quantified at micrograms/L levels in drinking water. Reporting limits as low as 20 micrograms/L are routinely achieved. Formaldehyde detection typically exceeds 90% at 20-200 micrograms/L. The laboratory procedure is presented in Appendix C.

SAMPLING

Samples were taken at existing domestic/irrigation wells at six sites in Ontario. These sites were screened and selected to ensure sampling integrity, relative to their construction. Selected wells were located for the most part in sandy shallow aquifers down gradient of cemeteries. Wells ranged in depth from 3 to 24 metres (see Appendix A). Sites CMF-1, 3 and 4 are actually located within the confines of the cemetery downgradient of the most filled part of the cemetery, (burial time ranges from 100 to 8 years ago). Separation distance from the potential source ranged between 500 and 2000 metres.

Samples were taken from cold water taps connected directly to plumbing from the well. All taps were purged for a period of five minutes before samples were taken.

Unfiltered, duplicate one litre samples were taken at each site. One litre screw cap amber coloured bottles containing no preservatives were used. To assure sample integrity, wells that conformed to proper well construction criteria were selected for sampling. Samples were shipped to the laboratory for analysis within 6 hours from time of sampling where they were refrigerated until analysis could be done (1-2 days). Samples were analyzed for formaldehyde, nitrates and phosphates. Bacteriological analyses were also done.

DISCUSSION

The investigators were particularly interested in the potential contamination of groundwater resulting from the use of certain chemicals used for the preservation of deceased human bodies. The chemical formaldehyde is of particular interest because of its

&potential human carcinogenic effects.

In order to gain some insight into the decomposition process, the investigators first attempted to theoretically predict the extent to which organic matter and other properties derived from a buried cadaver in the soil, could be broken down.

The human body has roughly the following composition (Van Haaren F.W.J., 1951):

water	-	64%
protein	-	20%
fat	-	10%
carbohydrates	-	1%
mineral salts	-	5%

The average weight of a corpse is assumed to be 65 kg. This assumption is based on the average weight of adults, children and emaciated corpses (from terminal illnesses).

65kg (total weight) - 6.60kg (fat) = 58.4kg
Based on a weight of 58.4kg, the average chemical loading per body,(kg) is:

water	-	37.38
protein	-	11.68
fat	-	5.84
carbohydrates	-	0.58
mineral salts	-	2.92

The decompositional product which may be of greatest environmental concern is nitrogen (a derivative of the body's protein content). This will be discussed in Part II of this discussion; Decompositional Products.

Formaldehyde Loading

If one assumes that all corpses are preserved with formaldehyde and that 50% of the chemical retains its chemical configuration, then the following is a theoretical loading estimation:

a) Average body weight = 58.4 kg
b) Standard cadaver preservation = 1 litre 2% formaldehyde solution / 5 kg body weight

- therefore 58.4 / 5 = 11.7 L formaldehyde / body
  = 11.7 L x 0.02 (2%)
  = 0.234 L of formaldehyde / body /2 (50%)
  = 0.117 L of formaldehyde / body

Using a maximum density of 500 bodies per acre, one will arrive at

a loading of:

500 bodies / acre x 0.117 L
= 58.5 L formaldehyde / acre over a period of 10 - 15 years
= 0.012 L formaldehyde / day

As an illustration, if the rechargeable volume of an aquifer is:

50,000 gpd (a small aquifer) = 227,3000 L/day
and
0.012 litres/day of formaldehyde is added daily,
then
the concentration of formaldehyde/litre =0.012/227,300

= 5.0 ng/L or 5ppt

A Ministry of the Environment hydrogeological study done for Blue Springs Creek, (Hydrogeology and Groundwater Model of the Blue Springs Creek IHD Representative Drainage Basin, Water Resources Report #10, 1978, p.28 - 36), indicated that the groundwater contribution to base flow measured 3.9 million Imperial gallons per day, an illustration of the actual storage capacity of aquifers in this area. Thus, the dilution capacity of the aquifer is actually close to 8 - 10 times greater than indicated here. This would result in a concentration for the above calculation of 0.5 ppt formaldehyde.

Under these circumstances, it is obvious that if the chemical does inadvertently get into the aquifer, the dilution factor would render it a low priority source of contamination.

In confirmation, the results of the study revealed extremely low levels of formaldehyde. One must note that a blank sample analysed during the study, had a reading of 7.29 ppb formaldehyde, indicating that samples may have a built in error factor of this magnitude. As a result, the actual concentrations of formaldehyde in the groundwater samples collected may be lower than those reported in Appendix B.

It must also be remembered that formaldehyde is a breakdown product of a number of chemicals and is produced from a number of human activities. Results indicate that cemeteries are not a significant contributing source of formaldehyde to groundwater.

Decompositional Products

The decompositional product which may be of greatest environmental concern, is nitrogen (a derivative of the protein component mentioned above) equalling 1.87 kg per corpse. The maximum loading rate (using 500 bodies per acre), is assumed to be:

500 x 1.87 kg N
= 935 kg N / acre

Consider an aquifer with a rechargeable volume of 227,300 lpd

then the concentration would be: 935 / 227,300 L
= 0.0041 kg / L or 4113 mg / L
over a period of 10 - 15 years
= 0.90 mg N / L

One must remember that decomposition occurs gradually and thus nitrogen is released at a very insignificant rate.

Also, the number of bodies actually buried in a cemetery during one year varies considerably. It is unlikely that one block in a cemetery will be filled in one year. Loading is also drastically reduced in cemeteries using concrete vaults.

The established Drinking Water Standard for nitrate and nitrite nitrogen stands at 10.0 mg/L and 1.0 mg/L respectively.

The results of analyses done for nitrates, nitrites and phosphates indicate with the exception of one site, (the Woodhouse Cemetery site - nitrate) only very low levels exist (<10 mg/L).

There is no drinking water standard set for Phosphorus/phosphates as it is not considered a health or aesthetic hazard. Restrictive levels are established only for discharge volumes to the Great Lakes as phosphates are nutrients which, in high concentrations stimulate algae blooms, (which use up available oxygen, and consequently threaten aquatic life).

The results of six sites that were sampled in this study, are presented in Appendix B.

CONCLUSIONS

The analysis of groundwater samples collected at wells located downgradient of six cemeteries sites in Ontario, indicated that cemeteries are not a significant source of groundwater contamination by formaldehyde. In addition, the calculated loading estimates for formaldehyde and nitrates being released from cemeteries supports a low potential for groundwater contamination.

The concentration of nitrate exceeded the Ontario Drinking Water Objective in groundwater samples collected at one cemetery site. The sources of nitrates at this site were not investigated further, and may be the result of nitrate loadings from other practices.

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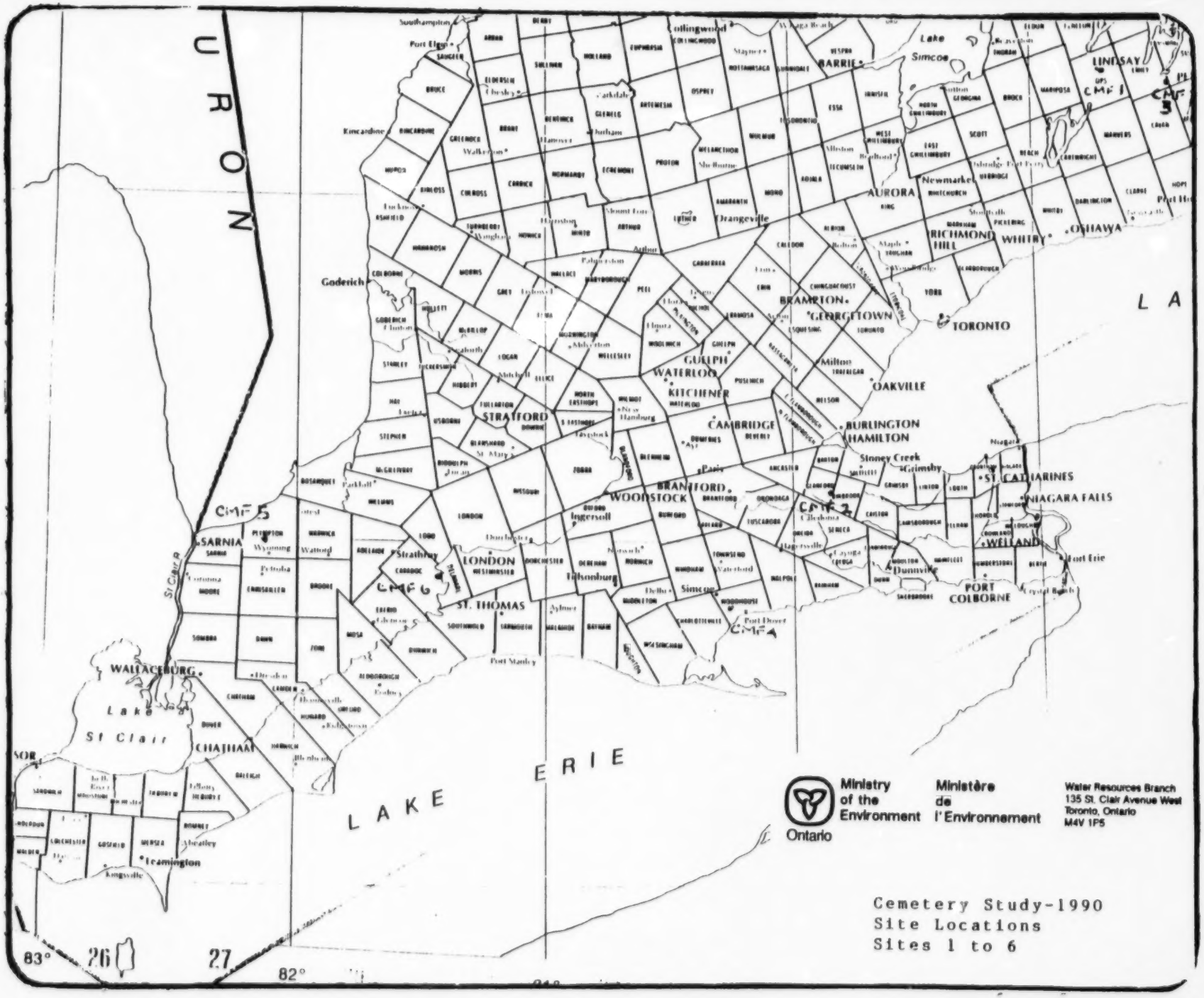
APPENDIX A - SITES
APPENDIX B - RESULTS
APPENDIX C - LAB PROCEDURE FOR THE TESTING OF FORMALDEHYDE
DIAGRAM 1 - SITE LOCATIONS


LAKE ERIE
LAKE HURON
Lake St Clair
Ministry of the Environment
Ministère de l'Environnement
Ontario
Water Resources Branch
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5
Cemetery Study-1990
Site Locations
Sites 1 to 6
SARNIA
WALLACEBURG
CHATHAM
LONDON
STRATFORD
GODERICH
KITCHENER
WATERLOO
GUELPH
CAMBRIDGE
BRANTFORD
WOODSTOCK
ST. THOMAS
TILLSONBURG
INGERSOLL
BURLINGTON
HAMILTON
OAKVILLE
MILTON
BRAMPTON
GEORGETOWN
TORONTO
MISSISSAUGA
RICHMOND HILL
AURORA
NEWMARKET
BARRIE
ORILLIA
LINDSAY
OSHAWA
WHITBY
PORT COLBORNE
WELLAND
ST. CATHARINES
NIAGARA FALLS
DUNNVILLE
STONEY CREEK
GRIMSBY
TECUMSEH
LEAMINGTON
CMF 1
CMF 2
CMF 3
CMF 4
CMF 5
CMF 6
83°
82°
26
27

APPENDIX A
SAMPLING LOCATIONS – CEMETERY STUDY 1990

SITE #	WELL REC.	COUNTY	TOWNSHIP	LOT/CON.	WELL TYPE	USE	DEPTH (m)
CMF-1	64-6530	VICTORIA	OPS	17/5	DRILLED	D	6.7
CMF-2	68-1313	WENTWORTH	BINBROOK	B3 2/3	DRILLED	D	24.4
CMF-3	64-5415	VICTORIA	EMILY	12/1	DRILLED	CO	32
CMF-4	44-1940	NORFOLK	WOODHOUSE	1/1	DRILLED	IR	6.1
CMF-5	–	LAMBTON	PLYMPTON	16/1	DUG	D	N/A
CMF-6	–	MIDDLESEX	CARADOC	18/2	DUG	D	N/A

D – DOMESTIC

CO – COMMERCIAL

IR – IRRIGATION

APPENDIX B
CEMETERIES STUDY 1990

SITE #	SITE	LOCATION	DATE	FORMAL.PPM*	NITRATE PPM	NITRITE PPM	PHOSPHATES PPM
CMF-1	RIVERSIDE CEMETERY	LINDSAY	24/7/90	0.0051	4.3000	0.005<T	0.02<W
CMF-1	RIVERSIDE CEMETERY	LINDSAY	24/7/90	0.0058	4.2500	0.005<T	0.02<W
CMF-2	BINBROOK BAPTIST CEM.	BINBROOK	15/08/90	0.0160	0.005<T	0.0080	0.0010<T
CMF-2	BINBROOK BAPTIST CEM.	BINBROOK	15/08/90	0.0300	0.005<T	0.0060	<0.0005<W
CMF-3	EMILY PRES.	OMEEMEE	14/08/90	0.0066	0.415	0.0030<T	<0.0005<W
CMF-3	EMILY PRES.	OMEEMEE	14/08/90	0.0073	0.400	0.0030<T	<0.0005<W
CMF-4	WOODHOUSE UNITED	SIMCOE	15/08/90	0.0074	13.800	<0.0010<W	<0.0005<W
CMF-4	WOODHOUSE UNITED	SIMCOE	15/08/90	0.0067	14.300	<0.002<T	<0.0005<W
-	BLANK	-	15/08/90	0.0073	-	-	-
CMF-5	MOUNT CALVARY CEM.	SARNIA	23/08/90	0.0016	1.350	0.010<T	<0.02<W
CMF-5	MOUNT CALVARY CEM.	SARNIA	23/08/90	0.0010	1.350	0.010<T	<0.02<W
CMF-6	UNITED CHURCH CEM.	LONDON	22/08/90	0.0016	8.300	0.010<T	<0.02<W
CMF-6	UNITED CHURCH CEM.	LONDON	22/08/90	0.0021	8.200	<0.005<W	<0.02<W

*FORMALDEHYDE

APPENDIX C

LABORATORY PROCEDURE FOR THE TESTING OF FORMALDEHYDE IN DRINKING WATER

Formaldehyde is readily quantified at micrograms/L levels in drinking water. The analyte present in 1L water samples is derivatized with 2,4 dinitrophenlyhydrazine (DNPH), in a 2M acid medium and then extracted with chloroform. After the solvent is exchanged for methanol, the product is separated and quantified using reverse phase liquid chromatography with UV detection (365 nm). Reporting limits as low as 20 micrograms/L are routinely achieved. Formaldehyde recovery typically exceeds 90% at 20-200 micrograms/L. The samples are accompanied by sets of blanks and spikes specified by a quality assurance/quality control plan, (Tomkins et Al. P.835 Analytical Chemistry vol 72, no.5, 1989).

To exactly 500 mL water samples, 40 mL of 2,4-DNPH solution (15g DNPH crystalline solid Merck dissolved in 6 litres of distilled water containing 2N HCl/the solution purified by extraction with chloroform) was added, and the solution mixed thoroughly for 15 minutes. The solution was then extracted with 3x50 mL chloroform and the chloroform extract washed with 2 N HCl (100mL) followed by washing with distilled water (100mL). The extract was then evaporated to dryness in a rotary evaporator at 35^0 C under reduced pressure, and the residue dissolved in acetonitrile. The solution after appropriate dilution was then analyzed by HPLC/UV using the optimized chromatographic conditions. A reference formaldehyde-DNPH derivative was used for calibration by peak area method using retention times confirmatory technique.

QA/QC studies involved running one method blank (distilled water), one spiked water sample (distilled water) and one duplicate for all samples taken in this project.